discharged and there results a malfunction of the piezoelectric actuator. As a result, fuel is not injected when fuel is to be injected. On the other hand, if the cable is disconnected after charging, the piezo-stack cannot be discharged and there results a continuous fuel injection even after the predetermined injection period. Some of the fuel injection system is provided with a fail-safe function that functions mechanically to stop the fuel injection after elapse of a certain time so that a serious failure can be avoided.

JP-A-1-202177 teaches to detect a voltage between both ends of a current detection resistor provided in a current supply path connected to the piezo-stack during the charging operation. If the detected voltage value is lower than a predetermined threshold value, it is determined that normal charging current does not flow due to conduction failure of the cable. The charging to the piezo-stack or a set of the piezo-stacks having a common cable is disabled. However, because the abnormality is detected based on the charge/discharge current, the abnormality detection timing is limited to the start or end of the injection period.

As a result, although the complete disconnection can be detected definitely, jittering in which disconnection and reconnection due to irregular contact to the connection terminal cannot always be detected. Moreover, in the case of jittering, which is different from the complete disconnection in which the piezo-stack already loses charge/discharge capability, it often happens that the fuel injection cannot be stopped due to disabled discharge even though the mechanical fail-safe function is operated.

Please replace the paragraphs beginning at page 5, line 25, with the following rewritten paragraphs:

Furthermore, the CPU 61 controls the operation so that the injection properly corresponds to the operation condition detected by various sensors. To accomplish this operation, a pressure sensor 62 is provided on the common rail 54, the CPU 61 controls a metering valve 52 based on the common rail pressure so as to adjust the pressurized fuel supply volume supplied to the common rail 54.

FIG. 2 shows the injector 1. The injector 1 is fixed so that the lower side section of the injector 1 in the figure is projected into the combustion chamber through the combustion chamber wall of the engine. The injector 1 comprises a nozzle section 1a, a back-pressure control section 1b, and a piezoelectric actuator 1c in order from the bottom.

Please replace the paragraphs beginning at page 7, line 4, with the following rewritten paragraphs:

The back-pressure chamber 106 communicates normally to a valve chamber 110 of the back-pressure control section 1b through an orifice 109. The valve chamber 110 is formed in a conical shape having an upper surface 1101 upward. The uppermost portion of the upper surface 1101 has a low pressure port 110a that communicates to the low pressure chamber 111. The low pressure chamber 111 communicates to a low pressure passage 102 that communicates to the drain line 56. The bottom surface of the valve chamber 110 has a high pressure port 110b that is connected to the high pressure passage 101 through the high pressure control passage 108.

A ball 123 formed by horizontally cutting the lower side of a spherical ball is disposed in the valve chamber 110. The ball 123 serves as a valve body that is

movable vertically. The cut surface seats on the valve chamber bottom surface that serves as a valve seat (high pressure side seat) 1102 so as to close the high pressure port 110b when the ball 123 moves down and shuts down the high pressure control passage 108.

On the other hand, when the ball 123 is lifted, the ball 123 seats on the upper surface that serves as a valve seat (low pressure side seat) 1101 so as to close the low pressure port 110a and shuts down the valve chamber 110 from the low pressure chamber 111. Thereby, the back-pressure chamber 106 communicates to the low pressure chamber 111 through the out orifice 109 and the valve chamber 110 when the ball 123 is lowered, and the back-pressure of the needle 121 is reduced and the needle 121 is unseated. On the other hand, when the ball 123 is lifted, the back-pressure chamber 106 is shut down from the low pressure chamber 111 and communicates with only the high pressure passage 101, the back-pressure of the needle 121 increases and the needle is seated.

The ball 123 is press-driven by means of the piezoelectric actuator 1c. Two pistons 124 and 125 having different diameters are held slidably in a vertical hole 112 formed vertically above the low pressure chamber 111. The piezo-stack 127 that expands or contracts in the vertical direction is disposed above the upper larger-diameter piston 125.

Please replace the paragraphs beginning at page 11, line 17, with the following rewritten paragraphs:

The current supply passages 22a and 22b are used commonly for the respective piezo-stacks 127A to 127D. The piezo-stacks 127A to 127D are selected as the drive target as described hereinunder. Selection switching elements 25A, 25B, 25C, 25D, 25E, and 25F are connected to the respective piezo-stacks 127A to 127D in series. The first type selection switching elements 25A to 25D are connected to the piezo-stacks 127A to 127D through ground side connection terminals 201A, 201B, 201C, and 201D provided correspondingly to each cylinder. Current supply cables 203A, 203B, 203C, and 203D connect between the connection terminals 201A to 201D and the piezo-stacks 127A to 127D, respectively. A selection switching element 25A to 25D is connected to a respective piezo-stack 127A to 127D, which corresponds to the injection cylinders, and is turned on selectively when fuel is to be injected to the corresponding injection cylinder.

The second type selection switching elements 25E and 25F are connected to the piezo-stacks 127A to 127D through the power source side (non-ground side) connection terminals 201E and 201F. The sections between the power source side connection terminals (common terminal) 201E and 201F (COMA and COMB) and the piezo-stacks 127A to 127D serves as fork current supply cables 203E and 203F. On the other hand, the current supply cable 203E is commonly used for both piezo-stack 127A and piezo-stack 127B, and the other current supply cable 203F is commonly used for both piezo-stacks 127C and piezo-stack 127D.

The selection switching element 25E serves to switch the current supply between ON and OFF to the bank of the injectors 1 (INJ1 and INJ2) of the #1 and #2 cylinders on which the piezo-stacks 127A and 127B are mounted. The selection switching element

25F serves to switch the current supply between ON and OFF to the bank of the injectors 1 (INJ3 and INJ4) of the #3 and #4 cylinders on which the piezo-stacks 127E and 127F are mounted. For example, even if any one of the current supply cables 203E and 203F is ground-shorted, the selection switching elements 25E and 25F corresponding to the ground-shorted current supply cable is turned off and the function of the other bank is ensured (limp home operating mode).

A MOSFET is used for each of the selection switching elements 25A to 25F, and the parasitic diodes (selection parasitic diode) 251A, 251B, 251C, 251D, 251E, and 251F are connected so as to function as the reverse bias with respect to the buffer capacitor 212.

Please replace the paragraph beginning at page 13, line 23, with the following rewritten paragraph:

Furthermore, the voltage between both ends (piezo-stack voltage) of each of the piezo-stacks 127A to 127D, that is the charging value, is supplied to the controller 28.

Please replace the paragraphs beginning at page 14, line 8, with the following rewritten paragraphs:

The controller 28 sets the ON period and OFF period of the first switching element 24a during charging control as described hereinunder, and generates the control signal to control the first switching element 24a. That is, the first switching element 24a is turned on to supply an increasing charge current to the first current

supply path 22a. When the charge current reaches a predetermined upper limit current value, the switching element 24a is turned off and enters into an OFF period.

At that time, because the counter electromotive force generated in the inductor 23 acts as a forward bias with respect to the parasitic diode 241b of the second switching element 24b, a decreasing flywheel current flows through the second current supply path 22b based on the energy stored in the inductor 23, and the piezo-stacks 127A to 127D are charged increasingly. When the charge current reaches the lower limit current value (approximately zero), the first switching element 24a is turned on and enters into an ON period again, and such operation is repeated (multiple switching system).

When the piezo-stack voltage reaches a predetermined voltage, the switching element 24a is turned OFF and the charging is completed. The piezo-stacks 127A to 127D are charged as described hereinabove, the piezo-stacks 127A to 127D are resultantly expanded so as to press and lift the ball 123 with interposition of the displacement enlarging chamber 113.

ON and OFF periods of the second switching element 24b are set as described hereinunder during discharge control, and the control signal for controlling the second switching element 24b is produced.

Specifically, the second switching element 24b is turned on to supply increasing discharge current to the second current supply path 22b. When the discharge current reaches the predetermined current value (upper limit current value), the switching element 24b is turned off and enters into an OFF period. At that time, a large counter electromotive force is generated in the inductor 23, a flywheel current generated from

the energy stored in the inductor 23 flows through the first current supply path 22a, and the energy is recovered in the buffer capacitor 212.

Please replace the paragraphs beginning at page 15, line 27, with the following rewritten paragraphs:

If the piezo-stacks 127A to 127D are disabled so as to be discharged due to disconnection of the current supply cables 203A to 203F, the injector 1 injects fuel continuously even after the end of the fuel injection period specified by the injection signal. However, the injector 1, shown in FIG. 2, is provided with a mechanical fail-safe mechanism that closes the valve when the charged state time of the piezo-stack 127 exceeds a predetermined period.

Specifically, the injector 1 pressurizes the fuel in the displacement enlarging chamber 113 by means of expansion of the piezo-stack 127 to generate the pressing pressure exerted on the ball 123. The fuel pressure becomes sufficiently larger to overcome the upward pressing force exerted on the ball 123 when the ball is lifted. Therefore, the pressurized fuel in the displacement enlarging chamber 113 leaks to the low pressure space such as the low pressure chamber 111 little by little from sliding section of the pistons 124 and 125. The lift magnitude of the ball 123 is decreased to reduce the fuel flow rate flowing from the back-pressure chamber 106 to the low pressure chamber 111, the back-pressure decreases gradually thereby, and at last the needle is seated to stop the fuel injection.

Please replace the paragraph beginning at page 17, line 5, with the following rewritten paragraph:

The first abnormality detection circuit section 29E detects the conduction abnormality such as disconnection of the current supply cables 203A, 203B, and 203E for the first and second piezo-stacks 127A and 127B and detects the conduction abnormality such as the contact failure to the connection terminals 201A, 201B, and 201E. The second abnormality detection circuit section 29F detects the conduction abnormality such as disconnection of the current supply cables 203C, 203D, and 203F for the third and fourth piezo-stacks 127C and 127D and detects the conduction abnormality such as contact failure to connection terminals 201C, 201D, and 201F. The abnormality detection signal generated from each of the abnormality detection circuit sections 29E and 29F is supplied to the CPU 61, and the CPU 61 performs the predetermined operation, if the abnormality is found, as described in the limp home mode.

Please replace the paragraphs beginning at page 18, line 3, with the following rewritten paragraphs:

The divided common terminal voltage Vcom is supplied to the (+) input terminal of a comparator 321. The comparator 321 compares the voltage of the (+) input terminal with a voltage Vref that is generated from a constant voltage generator 322 and supplied to the (-) input terminal, determines whether the common terminal voltage Vcom is larger than the reference voltage Vref specified by the constant voltage generator 322 or not, and generates a binary signal Vcomp ("H" or "L") depending on

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the comparison result. The binary signal is a signal that rises when the common terminal voltage exceeds the reference voltage (this signal is referred to as the first comparison signal). The magnitude of the reference voltage Vref is set in consideration of the target charge voltage of the piezo-stacks 127A and 127B so as to check whether the piezo-stacks 127A and 127B are in the charge holding state or not.

Furthermore, the binary signal Vcomp generated from the comparator 321 is inverted by means of a NOT gate circuit 323, and serves as the second comparison signal that rises when the common terminal voltage Vcom becomes lower than the reference voltage Vref opposite to the first comparison signal. The comparator 321, the constant voltage generator 322, and the NOT gate circuit 323 constitute a comparison means 32, and the comparison means 32 generates two comparison signals in inverse phase to each other.

The first comparison signal Vcomp is supplied to a set terminal (S) of an S-R flip-flop circuit 35 through the first AND gate circuit 33 that serves as the set input value fixing means. Furthermore, the second comparison signal is supplied to a reset terminal (R) of the S-R flip-flop circuit 35 through the second AND gate circuit 34 that serves as the reset input value fixing means.

A binary counter 36 receives the output (Q) of the S-R flip-flop circuit 35 as an input and serves as a counting means comprising two D-flip-flop circuits 361 and 362. The inverse output of the upper bit of the binary counter 36 is supplied to the third AND gate circuit 37 which also receives the output (Q) of the S-R flip-flop circuit 35. The output of the AND gate circuit 37 is supplied to the CPU 61 as the abnormality detection

signal for checking whether the conduction of either of the current supply cables 203A to 203F is abnormal or not.

The inverted phase output of the binary counter 36 is supplied to the first AND gate circuit 33 together with the comparison signal Vcomp of the first comparative signal. Therefore, the output value (non-inverted output Q) of the binary counter 36 remains at "L" until the binary counter 36 counts "10", and the first comparison signal is actually supplied to the set terminal of the S-R flip-flop circuit 35. When two pulses are supplied to the binary counter 36, the inverted phase output (inverted output of Q) of the binary counter 36 is changed from "H" to "L", and the set terminal of the S-R flip-flop circuit 35 is fixed at "L" and becomes insensitive to the first comparison signal.

An OR gate circuit 38 receives the first injection signal T1, corresponding to the first piezo-stack 127A, and the second injection signal T2, corresponding to the second piezo-stack 127B. The output of the OR gate circuit 38 is supplied to the second AND gate circuit 34 together with the second comparison signal. Therefore, while any one of the injection signal T1 and the injection signal T2 is being supplied, the second comparison signal is supplied to the reset terminal of the S-R flip-flop circuit 35.

Furthermore, a rising edge detection circuit 39 to which the logical output of the OR gate circuit 38 is supplied as an input, detects the rising edge of an output signal waveform of the OR gate circuit 38. When a rising edge is detected, reset signals are supplied to the respective D flip-flop circuit 361 and 362 of the binary counter 36.

Please replace the paragraph beginning at page 20, line 24, with the following rewritten paragraph:

FIG. 5, FIG. 6, and FIG. 7 are timing charts showing operation of each section of the respective abnormality detection circuits. The operation that is attained when a conduction failure is found on the current supply cables 203A and 203F during the charge holding period of the piezo-stacks 127A to 127D will be described with reference to these figures. The #1 and #2 cylinder abnormality detection circuit section 29E will be described.

Please replace the paragraph beginning at page 24, line 26, with the following rewritten paragraph:

According to the present embodiment, a conduction abnormality such as complete disconnection and jittering can be found based on a single abnormality detection signal. Furthermore, it is possible to distinguish between complete disconnection and jittering based on the output value (or inverted output value) of the upper bit D flip-flop circuit 362 when the abnormality detection is in “L” state that indicates the abnormality.

Please replace the paragraph beginning at page 25, line 20, with the following rewritten paragraph:

In this embodiment, the injector 1 stops fuel injection after elapse of a predetermined period by means of the mechanical fail-safe mechanism even if the conduction abnormality occurs after the piezo-stacks 127A to 127D are charged. However, it is possible to stop the fuel injection earlier by executing the next control

when the abnormality is found if the abnormality involves the current supply cable 203E coming off from the common terminal 201E or disconnection of the common section of the current supply cable 203E. FIG. 8 shows the state in which the piezo-stack 127A of the #1 cylinder injector INJ1 is disconnected.

Please replace the paragraphs beginning at page 27, line 9, with the following rewritten paragraphs:

In this embodiment, the abnormality detection circuits 29E and 29F of the first embodiment are modified as shown in FIG. 9.

The abnormality detection circuit section 29E for the #1 and #2 cylinders is provided with a counter 36 that serves as a counting means. The counter 36 receives the output of the comparator 321 that constitutes the comparison means 32, and counts the number of supplied pulses. The counter 36 is reset, for example, at the rising timing of the injection signal. The CPU 31 monitors the count value of the counter 36, for example, at the falling down timing of the injection signal, and determines whether the conduction abnormality occurs on the current supply cables 203A to 203F during charge holding state of the piezo-stack or not depending on the number of counts.

That is, if the count value is "0", it means that the common terminal voltage Vcom never falls down below the reference voltage Vref during the output period of the injection signal, and the injection is determined to be normal (FIG. 5). If the count value is "1", it means that the common terminal voltage Vcom falls down below the reference voltage once during the output period of the injection signal (FIG. 6). If the count value

is "2 or higher", it means that the common terminal voltage Vcom falls down and rises up several times across the reference voltage Vref, and jittering is determined (FIG. 7).